JC17 Rec'd PCT/PTO 20 JUN 2001

FORM-PTO-1390 (Rev. 12-29-99) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 032287-021

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5): UNASSIGNED 09/868706

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/AT99/00311	21 December 1999	21 December 1998

TITLE OF INVENTION
METHOD FOR TRANSMITTING DATA BLOCKS WITHOUT PREFIX IN THE GUARD INTERVAL, SAID DATA BLOCKS ARE DEMODULATED BY MEANS OF FFT WITH A LENGTH GREATER OR EQUAL THE SYMBOL PERIOD

APPLICANT(S) FOR DO/EO/US
Robert BALDEMAIR

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and the PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:

    International Preliminary Examination Report, Unexecuted Declaration

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
UNASSIGNED 09/868706	PCT/AT99/00311	032287-021

17. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1,000.00 (960)		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $860.00 (970)		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $710.00 (958)		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) $690.00 (956)		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00 (962)		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 860.00	
Surcharge of $130.00 (154) for furnishing the oath or declaration later than 20 ☐ 30 ☐ months from the earliest claimed priority date (37 CFR 1.492(e)).	$ -0-	

Claims	Number Filed	Number Extra	Rate		
Total Claims	4 -20 =	-0-	X$18.00 (966)	$ -0-	
Independent Claims	1 -3 =	-0-	X$80.00 (964)	$ -0-	
Multiple dependent claim(s) (if applicable)			+$270.00 (968)	$ -0-	
			TOTAL OF ABOVE CALCULATIONS =	$	
Reduction for 1/2 for filing by small entity, if applicable (see below).				$ -0-	-
			SUBTOTAL =	$ 860.00	
Processing fee of $130.00 (156) for furnishing the English translation later than 20 ☐ 30 ☐ months from the earliest claimed priority date (37 CFR 1.492(f)).			+	$ -0-	
			TOTAL NATIONAL FEE =	$ 860.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 (581) per property +				$ -0-	
			TOTAL FEES ENCLOSED =	$ 860.00	
				Amount to be: refunded	$
				charged	$

a. ☐ Small entity status is hereby claimed.

b. ☒ A check in the amount of $ 860.00 to cover the above fees is enclosed.

c. ☐ Please charge my Deposit Account No. 02-4800 in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

d. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-4800. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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Kenneth B. Leffler
SIGNATURE

Kenneth B. Leffler
NAME

36,075
REGISTRATION NUMBER

Patent
Attorney's Docket No. 032287-021

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	
	)	
Robert BALDEMAIR	)	Group Art Unit: UNASSIGNED
	)	
Application No.: UNASSIGNED	)	Examiner: UNASSIGNED
	)	
Filed: June 21, 2001	)	
	)	
For: METHOD FOR TRANSMITTING DATA BLOCKS WITHOUT PREFIX IN THE GUARD INTERVAL, SAID DATA BLOCKS ARE DEMODULATED BY MEANS OF FFT WITH A LENGTH GREATER OR EQUAL THE SYMBOL PERIOD	)	

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to examination, please amend the above-identified application as follows:

IN THE CLAIMS:

Please replace claims 3 and 4 as follows:

3. (Amended) Method according to claim 1, **wherein** the receiver transformation length L of the Fast Fourier Transform (FFT) equals the double transformation length 2.M.

4. (Amended) Method according to claim 1, **wherein** the guard interval is transmitted each time before or after a transmitter block.

REMARKS

The above changes to the claims have been made to delete multiple dependency of the claims, to round out the scope of patent protection being sought, and generally to place the claims in better condition for examination on the merits.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: _____
Kenneth B. Leffler
Registration No. 36,075

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Alexandria, Virginia 22313-1404
(703) 836-6620

Date: June 20, 2001

Attachment to Amendment dated June 20, 2001

Marked-up claims 3 and 4

3. (Amended) Method according to claim 1 [or 2], **wherein** the receiver transformation length L of the Fast Fourier Transform (FFT) equals the double transformation length 2.M.

4. (Amended) Method according to claim 1[, 2 or 3], **wherein** the guard interval is transmitted each time before or after a transmitter block.

PATENT COOPERATION TREATY

Sender: INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

To:
GIBLER, Ferdinand
Dorotheergasse 7
A-1010 Wien
AUSTRIA

NOTIFICATION OF THE TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY SEARCH REPORT

(Rule 71.1 PCT)

Mailing date:
(Day/month/year) 23.03.2001

Reference of the applicant or the attorney
24742/re

IMPORTANT NOTIFICATION

International Application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/AT99/00311	21/12/1999	21/12/1998

Applicant
TELEFONAKTIEBOLAGET LM ERICSSON et al.

1. The applicant is notified that the International Preliminary Examining Authority herewith transmits the international preliminary examining report drawn up in connection with the international application together with the enclosures pertaining to it, if any.

2. A copy of the report, together with the enclosures pertaining to it, if any, will be transmitted to the International Bureau for passing it on to all the Offices elected.

3. Upon request of an elected Office, the International Office will have the report (but not the enclosures) translated into English and will transmit it to this Office.

4. REMINDER
For the introduction to the national phase, the applicant has to undertake certain Actions (to file translations and to pay national fees) with each of the elected Offices within the period of 30 months from the priority date (or in some Offices even later) (Article 39 (1)) (also compare the information given by the International Bureau in form PCT/IB/301).

If an elected Office requests a translation of the International Application, this translations needs to also contain translations of all the enclosures to the international preliminary examination report. It is the duty of the applicant to have such translations made and to send them directly to the elected offices of concern.
Further details as to the relevant time limits and requirements of the elected Offices may be taken from Volume II of the PCT-Guide for applicants.

Name and mailing address of the International Search Authority
European Patent Office

Authorized Officer
Barrio Baravano, A

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(Article 36 and Rule 70 PCT)

Reference of Applicant or Attorney

FURTHER STEPS compare Notification of the Transmittal of the international preliminary examination report (Form PCT/IPEA/416)

24742/re

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/AT99/00311	21/12/1999	21/12/1998

International Patent Classification (IPC) or national classification and IPC
H04L27/26

Applicant
TELEFONAKTIEBOLAGET LM ERICSSON et al.

1. This international preliminary examination report was drawn up by the International Preliminary Examining Authority and transmitted to the applicant according to Article 36.

2. This REPORT comprises a total of 5 sheets including this cover sheet.

   ☒ Enclosures are sent together with this Report; these enclosures are sheets with descriptions, claims and/or drawings that have been amended and that form the basis of this Report, and/or sheets with corrections made with this Office (compare Rule 70.16 and Chapter 607 of the Administration Guidelines to PCT).

   These enclosures comprise a total of 4 sheets.

3. This report contains indications regarding the following points:

I	☒	Basis of the report
II	☐	Priority
III	☐	No expert's opinion on novelty, inventive work and commercial applicability
IV	☐	Lack of unity of invention
V	☒	Justified declaration according to Article 35(2) regarding novelty, inventive work and commercial applicability; documents and explanations in support of this declaration
VI	☐	certain documents cited
VII	☐	certain shortcomings of the international application
VIII	☐	certain remarks upon the international application

Filing date of the demand	Date of completion of this report
09/06/2000	23.03.2001

Name and mailing address of the International Search Authority
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Authorized Officer
Keller, M

Tel.: + 49 89 2399 8807

INTERNATIONAL PRELIMINARY EXAMINATION REPORT International application no. PCT/AT99/00311

I. Basis of the report

1. This report was drawn up on the basis of *(substitute sheets that were submitted to the receiving Office upon request under Article 14, are understood within the frame of this report as being „originally filed" and are not annexed as they do not contain any amendments)*:

Description, pages:

3-9	original version		
1,2,2A	filed	27/01/2001 with letter dated	23/01/2001

Claims, No.:

1-4	filed	27/01/2001 with letter dated	23/01/2001

Drawings, sheets:

1/2,2/2	original version

2. With regard to **language:** all the above mentioned constituent parts were available to the Authority in the language in which the international application was filed or they were filed in said language as far as nothing else is indicated under this item.

The constituent parts were available in the language or were filed in this language: the language of concern is

- ☐ the language of the translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to the **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was drawn up on the basis of sequence listing which

- ☐ is included in the international application in written form.
- ☐ was filed together with the international application in computer readable form.
- ☐ was filed with the Authority in written form at a later date.
- ☐ was filed with the Authority in computer readable form at a later date.
- ☐ Declaration was submitted that the subsequently filed written sequence listing does not depart from the subject matter of the disclosure of the international application at the time of application.
- ☐ Declaration was submitted that the information seized in computer readable form correspond to the written sequence listing.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT International application no. PCT/AT99/00311

4. On account of the amendments, the following documents have become void:

   ☐ description, pages:
   ☐ claims, No:

   ☐ drawings, sheet:

5.

   ☐ This report was drawn up without taking (some of) the amendments into consideration, since these amendments depart from the subject matter of disclosure in the version as originally filed for the reasons indicated above (Rule 70.2(c)).

   (Substitution sheets containing such amendments have to be indicated under Item 1; they are to be enclosed to this report).

6. Additional remarks, if any:

V. Justified declaration under Article 35(2) with regard to novelty, inventive work and commercial applicability; documents and explanations in support of this declaration

1. Declaration

Novelty (N)	yes:	claims 1-4
	no:	claims
Inventive work (IW)	yes:	claims 1-4
	no:	claims
Commercial applicability (CA)	yes:	claims 1-4
	no:	claims

1. Documents and explanations
   compare annexed sheet

To Point V

1). According to the appointed title, the international patent application PCT/AT99/00311 is directed to a method of transmitting data blocks without prefix in the guard interval, said data blocks are demodulated by means of FFT with a length greater than or equal to the symbol period.

Claim 1 claims a method of transmitting data by a multiple carrier method.

2). In the specification (more specifically on pages 1 and 2), the applicant fully rates the **state of the art** which is illustrated in the preamble of Claim 1. The features of the preamble of claim 1 are to be found in the document **D1** = US-A-5 357 502. Accordingly, D1 discloses a method of transmitting data by a multiple carrier method, in which the data are combined in a transmitter into a transmitter signal in the form of transmitter blocks with the same number M of information symbols, are modulated and transmitted by an Inverse Fast Fourier Transform (IFFT) of the transformation length M and are demodulated in a receiver by the Fast Fourier Transform (FFT), wherein, on the transmitter side, one guard interval for equalization on the side of the receiver is inserted each between the transmitter blocks and transmitted together with them, said guard interval having a length P that is greater than or equal to the memory length of the transmission channel, and wherein demodulation is carried out in the receiver by means of the Fast Fourier Transform (FFT) with a receiver transformation length L that is greater than or equal to the sum of the transformation length M and the length P of the guard interval.

The drawbacks of the prior art are explained from page 1, line 26 to page 2, first paragraph and on page 3, last paragraph of the text. To avoid interferences, that is in order to prevent two consecutive blocks on the receiver side from overlapping, a guard interval is to be inserted between the discrete blocks on the transmitter side. For ease of equalization when using the FFT in the receiver, a cyclical prefix consisting of a number of recurrent data from each block, is additionally transmitted in the guard interval. The *advantage* of the relatively easy equalization entails however the *disadvantage* of the data being transmitted in the prefix without any gain of information and requiring part of the transmitting power available for themselves.

3). It is therefore the **object of the invention** (see page 2, third paragraph from the bottom) to indicate a method that makes it possible to equalize on the receiver side the transmitted transmitter signal without transmitting useless information, thus improving the transmitting power that is available for data transmission.

4). The object of the invention is solved by the advantageous cooperation of the technical features recited in Claim 1. The method of Claim 1 is illustrated in Figure 3.
The characteristic of Claim 1 states that the method
is **characterized in that**
the signal values of the transmitter signal contained in the guard interval have a signal amplitude of zero.

The method described in Claim 1 develops advantageous effects as it has been explained from page 2 (last paragraph) to page 2a (first paragraph) of the specification.

5). The totality of all the technical features of Claim 1 **have not** yet been disclosed by any single document of the International Search Report. Accordingly, the subject matter of Claim 1 thus complies with the criterion of novelty (Art. 33 (1) and (2) PCT).
Furthermore, neither the document D1 nor the remaining documents cited in the International Search Report are making the subject matter of Claim 1 obvious. As a result thereof, the requirements with regard to inventiveness of the subject matter claimed are met (Article 33(1) and (3) PCT).

The subject matter of Claim 1 may among others be commercially used for multiple carrier methods, e.g. DMT (Discrete Multitone) in a transmission channel.

Accordingly, the conditions of Article 33(1) and (4) PCT with regard to industrial applicability are fulfilled.

6). The dependable claims 2 to 4 define specific interpretations of the method according to claim 1 and also meet with the requirements regarding novelty, inventiveness and industrial applicability (Art. 33(2) to (4) PCT).

AMENDED SHEET

Method for transmitting data blocks without prefix in the guard interval, said data blocks are demodulated by means of FFT with a length greater than or equal to the symbol period

The invention relates to a method of transmitting data by means of a multiple carrier method, e.g. DMT (Discrete Multitone) in a transmitter channel, in which the data are combined in a transmitter into a transmitter signal in the form of transmitter blocks with the same number M of information symbols, are modulated and transmitted by an Inverse Fast Fourier Transform (IFFT) of the transformation length M and are demodulated in a receiver by the Fast Fourier Transform (FFT), wherein, on the transmitter side, one guard interval for equalization on the side of the receiver is inserted each between the transmitter blocks and transmitted together with them, said guard interval having a length P that is greater than or equal to the memory length of the transmission channel, and wherein demodulation is carried out in the receiver by means of the Fast Fourier Transform (FFT) with a receiver transformation length L that is greater than or equal to the sum of the transformation length M and the length P of the guard interval.

Many of the known transmission methods use the available frequency range of a transmission channel by properly modulating the data to be transmitted. In frequency-division multiplexing, the frequency spectrum is divided into several slots through which information is transmitted. Such methods have become known under the designations multiple carrier method, Orthogonal Frequency Division Multiplex (OFDM) and Discrete Multitone Technique (DMT).

A predetermined, broad frequency band is thereby subdivided into a host of very narrow subchannels over which data are transmitted. For this purpose, the data are combined in a transmitter into information blocks of the same length and are modulated by an Inverse Fast Fourier Transform that effects a filtration of the subchannels with frequency-shifted versions of a prototype filter. The transmitter serially transfers the thereby generated transmitter block onto the transmission line. The memory of the dispersive transmission channel generally causes consecutive blocks on the receiver side to interfere. In order to avoid overlapping on the receiver side, a guard interval must be inserted between the discrete blocks on the transmitter side. Demodulation of the data occurs in the receiver by means of a Fast Fourier Transform (FFT), the input samples being transformed in blocks into spectral values. When using the FFT in the receiver, equalization can be considerably simplified by also transmitting in the guard interval a cyclical prefix consisting of a number of recurrent data from each block, said data being transmitted within the guard interval before the block with respect to time. The transformation length L of the FFT thereby equals the length M of the data blocks transmitted. In

order to obtain efficient equalization, the guard interval or the cyclical prefix respectively must be greater than or equal to the memory length of the channel. The advantage of the relatively easy equalization entails however the disadvantage of the data being transmitted in the prefix signal without any gain of information and requiring part of the transmitting power available for themselves.

In the OFDM method for radio transmission of data which is indicated in US Patent No. 5 357 502, the transmission of the information is carried out by means of N orthogonal carrier frequencies that are modulated by an Inverse Fast Fourier Transform. In order to avoid interferences between the discrete carrier frequencies, the time windows of these filters are not chosen to be rectangular like in the conventional OFDM methods, they are rather selected according to the Nyquist criterion. N data values at a time are thereby combined into information blocks according to the number of carrier frequencies. Figure 4 of this document shows the Nyquist interval used for transmitting, a guard interval in which a prefix with useless information is also transmitted being left free between the transmitter blocks.

Furthermore, EP 0 682 426 A discloses an OFDM transmission system with Fast Fourier Transform (FFT) and quadrature amplitude modulation (QAM), a pilot signal being transmitted together with a portion of the block of information in the guard interval of each block of information transmitted.

It is therefore the object of the invention to indicate a method of the type mentioned herein above that makes equalization of the transmitted transmitter signal on the receiver side possible without transmitting useless information at the same time, thus increasing the transmitting power available for data transmission.

This is achieved according to the invention in that the signal values of the transmitter signal contained in the guard interval have a signal amplitude of zero.

The advantage of the method according to the invention is that in the guard interval no signal or power needs to be transmitted, which entails that the mean transmitting power is thereby reduced, but that the equalization of the signal transmitted can be carried out with relatively little expenditure. Assuming a predetermined power density, it is therefore possible to increase the transmitting power for the blocks of information within a transmission channel.

According to an exemplary embodiment of the invention, demodulation may advantageously be conducted in segmenting the receiver signal in the receiver into blocks of the length M+P and in lengthening every single block by appending zeros to the receiver transformation length L.

In another embodiment of the invention there may be provided that the receiver transformation length L of the Fast Fourier Transform (FFT) equals the double transformation length 2.M.

According to still another embodiment of the invention there may be provided that the guard interval is transmitted each before or after a transmitter block.

The invention will be described more fully herein after with the help of the embodiment illustrated in the drawing.

Figure 1 shows a transmitter signal when using a cyclical prefix according to prior art;

Figure 2 shows the decomposition into blocks of the length M of a receiver signal generated by the transmitter signal according to Figure 1;

Figure 3 shows a prefix-free transmitter signal according to an embodiment of the method according to the invention;

Figure 4 shows the decomposition into blocks of the length M+P of a receiver signal generated by the transmitter signal according to Figure 3 and

Figure 5 shows the demodulation of the receiver signal according to Figure 4 by an FFT of the length 2M.

(Continued on page 3 of the original description)

International Patentapplication PCT/AT99/00311
Applicant: Telefonieskiebolaget LM Ericsson et al.

NEW CLAIMS

Amended sheet

1. Method of transmitting data by a multiple carrier method, e.g. DMT (Discrete Multitone) in a transmission channel in which the data are combined in a transmitter into a transmitter signal in the form of transmitter blocks with the same number M of information symbols, are modulated and transmitted by an Inverse Fast Fourier Transform (IFFT) of the transformation length M and are demodulated in a receiver by the Fast Fourier Transform (FFT), wherein, on the transmitter side, one guard interval for equalization on the side of the receiver is inserted each between the transmitter blocks and transmitted together with them, said guard interval having a length P that is greater than or equal to the memory length of the transmission channel, and wherein demodulation is carried out in the receiver by means of the Fast Fourier Transform (FFT) with a receiver transformation length L that is greater than or equal to the sum of the transformation length M and the length P of the guard interval, **wherein** the signal values of the transmitter signal contained in the guard interval have a signal amplitude of zero.

2. Method according to claim 1, **wherein** the receiver signal is segmented in the receiver into blocks of the block length M+P and that each of these blocks is lengthened by appending zeros to the receiver transformation length L.

3. Method according to claim 1 or 2, **wherein** the receiver transformation length L of the Fast Fourier Transform (FFT) equals the double transformation length 2.M.

4. Method according to claim 1, 2 or 3, **wherein** the guard interval is transmitted each time before or after a transmitter block.

METHOD FOR TRANSMITTING DATA BLOCKS WITHOUT PREFIX IN THE GUARD INTERVAL, SAID DATA BLOCKS ARE DEMODULATED BY MEANS OF FFT WITH A LENGTH GREATER OR EQUAL THE SYMBOL PERIOD

The invention relates to a method of transmitting data by means of a multiple carrier method, e.g. DMT (Discrete Multitone) in a transmitter channel, in which the data are combined in a transmitter into blocks with the same number M of information symbols, are modulated and transmitted by an Inverse Fast Fourier Transform (IFFT) and are demodulated in a receiver by the Fast Fourier Transform (FFT), wherein, on the transmitter side, one guard interval for equalization on the side of the receiver is inserted each between the blocks and transmitted together with them, said guard interval having a length P that is greater than or equal to the memory length of the transmission channel.

Many of the known transmission methods use the available frequency range of a transmission channel by properly modulating the data to be transmitted. In frequency-division multiplexing, the frequency spectrum is divided into several slots through which information is transmitted. Such methods have become known under the designations multiple carrier method, Orthogonal Frequency Division Multiplex (OFDM) and Discrete Multitone Technique (DMT).

A predetermined, broad frequency band is thereby subdivided into a host of very narrow subchannels over which data are transmitted. For this purpose, the data are combined in a transmitter into information blocks of the same length and are modulated by an Inverse Fast Fourier Transform that effects a filtration of the subchannels with frequency-shifted versions of a prototype filter. The transmitter serially transfers the thereby generated transmitter block onto the transmission line. The memory of the dispersive transmission channel generally causes consecutive blocks on the receiver side to interfere. In order to avoid overlapping on the receiver side, a guard interval must be inserted between the discrete blocks on the transmitter side. Demodulation of the data occurs in the receiver by means of a Fast Fourier Transform (FFT), the input samples being transformed in blocks into spectral values. When using the FFT in the receiver, equalization can be considerably simplified by also transmitting in the guard interval a cyclical prefix consisting of a number of recurrent data from each block, said data being transmitted within the guard interval before the block with respect to time. The transformation length L of the FFT thereby equals the length M of the data blocks transmitted. In order to obtain efficient equalization, the guard interval or the cyclical prefix respectively must be greater than or equal to the memory length of the channel. The advantage of the relatively easy equalization entails however the disadvantage of the data being transmitted in the prefix signal without any gain of information and requiring part of the transmitting power available for themselves.

It is therefore the object of the invention to indicate a method of the type mentioned herein above that makes equalization of the transmitted transmitter signal on the receiver side possible without

transmitting useless information at the same time, thus increasing the transmitting power available for data transmission.

This is achieved according to the invention by transmitting the guard interval free from signals or without prefix and by carrying out demodulation in the receiver by means of the Fourier Transform (FFT) with a length L that is greater than or equal to the sum of the length of the information blocks M and of the length P of the guard interval.

The advantage of the method according to the invention is that in the guard interval no signal or power needs to be transmitted, which entails that the mean transmitting power is thereby reduced, but that the equalization of the signal transmitted can be carried out with relatively little expenditure. Assuming a predetermined power density, it is therefore possible to increase the transmitting power for the blocks of information within a transmission channel. Alternatively, according to another feature of the invention, there may be provided that a desired signal, e.g. pilot signals, is transmitted, which is advantageous for timing recovery.

According to an embodiment of the invention, demodulation may advantageously be performed in that each information block of the length M+P that is to be transformed in the receiver is lengthened by appending zeros to the transformation length L.

In still another embodiment of the invention there may be provided that the transformation length L of the Fast Fourier Transform (FFT) equals the double length of the information block $2 \cdot M$. A very efficient implementation is possible in this case.

According to still another embodiment of the invention there may be provided that the guard interval is transmitted each before or after an information block.

The invention will be described more fully herein after with the help of the embodiment illustrated in the drawing.

Figure 1 shows a transmitter signal when using a cyclical prefix according to prior art;

Figure 2 shows the decomposition into blocks of the length M of a receiver signal generated by the transmitter signal according to Figure 1;

Figure 3 shows a prefix-free transmitter signal according to an embodiment of the method according to the invention;

Figure 4 shows the decomposition into blocks of the length M+P of a receiver signal generated by the transmitter signal according to Figure 3 and

Figure 5 shows the demodulation of the receiver signal according to Figure 4 by an FFT of the length

2M.

When transmitting data by means of a multiple carrier method, e.g. DMT (Discrete Multitone), the data to be transmitted are combined in a transmitter into the blocks with the same number M of information symbols represented herein after.

0^{th} block $A_0 = [A_0 \quad A_1 \quad \cdots \quad A_{M-1}]^T$

1^{st} block $A_M = [A_M \quad A_{M+1} \quad \cdots \quad A_{2M-1}]^T$

m^{th} block $A_{mM} = [A_{mM} \quad A_{mM+1} \quad \cdots \quad A_{mM+M-1}]^T$

The thus combined data are modulated and transmitted by an M points Inverse Fast Fourier Transform (IFFT). The transmitter block reads

$a_0 = [a_0 \quad a_1 \quad \cdots \quad a_{M-1}]^T = IFFT_M\{A_0\}$

$a_M = [a_M \quad A_{M+1} \quad \cdots \quad A_{2M-1}]^T = IFFT_M\{A_M\}$

$a_{mM} = [a_{mM}\, a_{mM+1} \quad \cdots \quad A_{mM+M-1}]^T = IFFT_M\{A_{mM}\}$

and is emitted in series at the transmitter output. The memory of the transmission channel generally causes consecutive blocks to interfere on the receiver side. To avoid this, the state of the art introduces a guard interval with a cyclical prefix between the discrete blocks, wherein, at the beginning of each block, the last P data of said block are transmitted once more, that is each block is cyclically carried on. If demodulation of the data in the receiver is carried out by means of a Fast Fourier Transform (FFT), equalization in the receiver may be considerably simplified using a cyclical prefix. Then, the transmitter signal has the following shape:

$$s^T = [a_{M-P}\, a_{M-P+1} \cdots a_{M-1}\, a_0\, a_1 \cdots a_{M-1}]\ [a_{2M-P}\, a_{2M-P+1} \cdots a_{2M-1}\, a_M\, a_{M+1} \cdots a_{2M-1}]\ [\cdots \quad (1)$$

$$= [\, a_0^T <^{M-1}_{M-P}> \; a_0^T \; a_M^T <^{M-1}_{M-P}> \; a_M^T \; \ldots] \qquad (2)$$

The notation $a_0^T <^{M-1}_{M-P}>$ means the elements M – *P* to M – 1 of the vector a_0. Fig. 1 is a schematic illustration of the transmitter signal when a cyclical prefix is used.
The receiver signal y_n is the convolution of transmitter signal and channel.

$$y_n = \{s_k * h_k\}(n) = \sum_{k=0}^{P} h_k s_{n-k} \qquad (3)$$

H_K is the channel and has *P* + 1 coefficients. The receiver divides the input sequence into blocks of the length *M* + *P* and rejects the first *P* values of each block, see *Fig.* 2.

$$\begin{aligned}
y_P^T &= [\, y_P \quad y_{P+1} \quad \cdots \quad y_{M+P-1} \,] \\
y_{M+2P}^T &= [\, y_{M+2P} \quad y_{M+2P+1} \quad \cdots \quad y_{2M+2P-1} \,] \\
&\vdots \\
y_{m(M+P)+P}^T &= [\, y_{m(M+P)+P} \quad y_{m(M+P)+P+1} \quad \cdots \quad y_{(m+1)(M+P)-1} \,] \\
&\vdots
\end{aligned}$$

The m^{th} block has a range of indices of $n = m\,(M + P) + P,\ m(M + P) + P + 1, \ldots, (m + 1)(M + P) - 1$. A Fast Fourier Transform (FFT) of the length *M* is now used on each of these blocks. For the block *m* we have

$$Y_l = \mathrm{FFT}_M \{y_{m(M+P)+P}\}(l) \qquad (4)$$

$$= \sum_{n=0}^{M-1} y_{m(M+P)+P+n}\, e^{-j\frac{2\pi}{M}nl} \qquad (5)$$

$$= \sum_{n=0}^{M-1} \sum_{k=0}^{P} h_k s_{m(M+P)+P+n-k}\, e^{-j\frac{2\pi}{M}nl} \qquad n' = n - k \qquad (6)$$

$$= \sum_{k=0}^{P} h_k \sum_{n'=-k}^{-k+M-1} s_{m(M+P)+P+n'}\, e^{-j\frac{2\pi}{M}(n'+k)l} \qquad n = n' \qquad (7)$$

$$= \sum_{k=0}^{P} h_k\, e^{-j\frac{2\pi}{M}kl} \sum_{n=-k}^{-k+M-1} s_{m(M+P)+P+n}\, e^{-j\frac{2\pi}{M}nl}\,. \qquad (8)$$

The term $H_l = \sum_{k=0}^{P} h_k \exp(-j\frac{2\pi}{M}kl)$ is the M-points FFT of the channel h_k, the coefficients h_{P+1} to h_{M-1} being zero. It would now be desirable to have equation (8) factorized, that is to have it resolved into the product of the FFT of h_k and of another multiplicand.

It cannot directly be seen that equation (8) may indeed be resolved into factors, because the summation index k of the first sum also appears in the second sum of equation (8). If it can be demonstrated that the value of the second sum is still independent of k, equation (8) may be factorized. The expression

$$S_l(k) = \sum_{n=-k}^{-k+M-1} s_{m(M+P)+P+n}\, e^{-j\frac{2\pi}{M}nl}, \qquad (9)$$

represents the l^{th} value of the FFT of the sequence $s_{m(M+P)+P+n}$, $n = -k, -k+1, \ldots, -k+M-1$. Considering that the value range for k is limited to 0, 1, ..., P, it may be seen from equation (1) that the limits of the summation always remain in the m^{th} block. Because the m^{th} transmitter block consists of $[a_{mM}^{T} < {}_{M-P}^{M-1} > a_{mN}^{T}]$ summation is made over exactly one complete period $a_{mM}, a_{mM+1}, \ldots, a_{mM+M-1}$.

In equation (9), it is true that $S_l(k)$ is independent of k, $S_l(k) = S_l$. This is to be made clear with the help of a simple example. Example:

M = 3
P = 2
M = 0

$$s^T = [a_1\ a_2\ a_0\ a_1\ a_2]$$
$$S_l(k) = \sum_{n=-k}^{-k+2} s_{2+n}\, e^{-j\frac{2\pi}{3}nl}$$
$$S_l(0) = s_2 + s_3\, e^{-j\frac{2\pi}{3}1l} + s_4\, e^{-j\frac{2\pi}{3}2l} = a_0 + a_1\, e^{-j\frac{2\pi}{3}1l} + a_2\, e^{-j\frac{2\pi}{3}2l}$$
$$S_l(1) = s_1\, e^{j\frac{2\pi}{3}1l} + s_2 + s_3\, e^{-j\frac{2\pi}{3}1l}$$
$$= a_2\, e^{j\frac{2\pi}{3}1l} + a_0 + a_1\, e^{-j\frac{2\pi}{3}1l} = a_0 + a_1\, e^{-j\frac{2\pi}{3}1l} + a_2\, e^{-j\frac{2\pi}{3}2l} = S_l(0)$$
$$S_l(2) = s_0\, e^{j\frac{2\pi}{3}2l} + s_1\, e^{j\frac{2\pi}{3}1l} + s_2$$
$$= a_1\, e^{j\frac{2\pi}{3}2l} + a_2\, e^{j\frac{2\pi}{3}1l} + a_0 = a_0 + a_1\, e^{-j\frac{2\pi}{3}1l} + a_2\, e^{-j\frac{2\pi}{3}2l} = S_l(0)$$

The identity $e^{-j\frac{2\pi}{M}nl} = e^{j\frac{2\pi}{M}(M-n)l}$ is of prime importance for the above mentioned conversions. Accordingly, equation (9) is the FFT of the block a_{mM}, which in turn is the IFFT of the data block A_{mM}.

Accordingly, (9) is nothing else than the piece of data A_{mM+l}.

If this result is inserted in equation (8), the following result is obtained

$$Y_l = \sum_{k=0}^{P} h_k \, e^{-j\frac{2\pi}{M}nl} A_{mM+l} \,. \qquad (10)$$

As it has already been mentioned, the remaining sum represents the FFT of the length M of the channel

$$Y_l = H_l A_{mM+l} \quad \text{with} \quad H_l = \sum_{k=0}^{P} h_k \, e^{-j\frac{2\pi}{M}kl} \,. \qquad (11)$$

Accordingly, equation (4) is nothing else than the l^{th} piece of data of the m^{th} block, A_{mM+l} multiplied by H_l, that is the spectrum of the channel h_k interpreted at the frequency $l\frac{2\pi}{M}$. In this case, equalization is particularly easy, each receiver value Y_l only needs to be multiplied by the reciprocal value of H_l.

The transformation length L of the FFT is identical with the length of the data blocks M whereas the length P of the guard interval, or of the cyclical prefix respectively, is greater than or equal to the memory length of the transmission channel.

To save the cyclical prefix of the transmitter signal, there is provided according to the invention to transmit the guard interval free from signal or without prefix, demodulation being conducted by means of the Fourier Transform (FFT) with a length L which is greater than or equal to the sum of the length of the information block M and of the length P of the guard interval. The guard interval may hereby be transmitted each either before or after one block of information.

First, the data to be transmitted A_k, k=0, 1, 2, ... are combined into blocks A_{mM} of the length M in the same way as in the known method of transmission. Modulation is also carried out by means of an M-points IFFT, $a_{mM} = IFFT_M\{A_{mM}\}$. Instead of cyclically repeating in the known way the last P values of each block transmitted, empty guard intervals of the length P are this time inserted, i.e., zeros are transmitted in these time periods. In this case, the transmitter signal reads

$$s^T = [a_0\, a_1 \ldots a_{M-1}\; 0\; 0 \ldots 0]\,[a_M\, a_{M+1} \ldots a_{2M-1}\; 0\; 0 \ldots 0]\,[\ldots \qquad (12)$$

$$= [a_0{}^T\, 0_P{}^T\, a_M{}^T \ldots 0_P{}^T] \qquad (13)$$

0_P is the zero vector of the length P. Fig. 3 shows the thus formed transmitter signal. If the guard interval is P symbols long and if M information symbols are blocked at a time in the transmitter, the incoming data y_n are first combined in the receiver into blocks of the length M+P, as it is shown in Fig. 4.

$$y_0^T = [y_0 \quad y_1 \quad \cdots \quad y_{M+P-1}]$$
$$y_{M+P}^T = [y_{M+P} \quad y_{M+P+1} \quad \cdots \quad y_{2(M+P)-1}]$$
$$\vdots$$
$$y_{m(M+P)}^T = [y_{m(M+P)} \quad y_{m(M+P)+1} \cdots \quad y_{(m+1)(M+P)-1}]$$
$$\vdots$$

The block m has a range of indices $n = m \cdot (M+P), m \cdot (M+P)+1, \ldots, (m+1) \cdot (M+P)-1$. An FFT with a block length L of at least M+P is used on each of these blocks of the length M+P. The transformed signal is now combined in the vector $Y_L = FFT_L\{y_{m(M+P)}\}$.

Like in the method of transmission known, equalization of the dispersive transmission channel occurs in the frequency range. After demodulation, the L elements of the vector $\mathbf{Y_L}$ are divided by samples of the spectrum of the channel. The vector $\mathbf{X_L}$ resulting therefrom is the L-points FFT of the data block $\mathbf{x} = [a_{mM}\ a_{mM+1} \cdots a_{mM+M-1}]$ presently transmitted

$$\mathbf{X_L} = FFT_L\{\mathbf{x}\}.$$

Because the modulation in the transmitter is conducted with an M-points IFFT,

$$\mathbf{x} = IFFT_M\{A_{mM}\},$$

the M-points FFT of the actual transmitter block $\mathbf{x}$ equals the transmitted data A_{mM}. The M-points FFT $\mathbf{X_M} = FFT_M\{\mathbf{x}\} = A_{mM}$ must therefore be computed from $\mathbf{X_L}$.

The calculation of the vector $\mathbf{X_M}$ from $\mathbf{X_L}$ is clearly possible, but the choice of L determines the complexity.

If the memory length of the channel is smaller than or equal to M ($P \leq M$), it makes sense to choose the transformation length L of the Fourier Transform (FFT) to equal the double length of the information block 2·M (L = 2M), as it is illustrated in Fig 5. Since the FFT of the transformation length 2M only needs to be interpreted at the even-numbered indices, a very efficient implementation is possible. The block to be transformed, which is only $M + P$ long, is lengthened to 2M by appending $M - P$ zeros. For the block m the following is obtained

$$Y_l = \mathrm{FFT}_{2M}\{y_{m(M+P)}\}(l) \tag{14}$$

$$= \sum_{n=0}^{M+P-1} y_{m(M+P)+n}\, e^{-j\frac{2\pi}{2M}nl} \tag{15}$$

$$= \sum_{n=0}^{M+P-1} \sum_{k=0}^{P} h_k s_{m(M+P)+n-k}\, e^{-j\frac{2\pi}{2M}nl} \qquad n' = n - k \tag{16}$$

$$= \sum_{k=0}^{P} h_k \sum_{n'=-k}^{-k+M+P-1} s_{m(M+P)+n'}\, e^{-j\frac{2\pi}{2M}(n'+k)l} \qquad n = n' \tag{17}$$

$$= \sum_{k=0}^{P} h_k\, e^{-j\frac{2\pi}{2M}kl} \sum_{n=-k}^{-k+M+P-1} s_{m(M+P)+n}\, e^{-j\frac{2\pi}{2M}nl}\,. \tag{18}$$

Depending upon the value of k, the summation begins over n for $k = 0$ at $n = 0$ until $n = -P$ at $k = P$, that is $s_{m(M+P)-P}$ to $s_{m(M+P)}$. Except for $s_{m(M+P)}$ however, all these values are equal to zero as a result of the zeros in the guard interval. Therefore, the summation may always be started at $n = 0$, irrespective of k.

In dependence on k, the upper summation limit can accept the values M – 1 to M + P – 1, the corresponding signal elements are $s_{m(M+P)+M-1}$ to $s_{m(M+P)+M+P-1}$. $s_{m(M+P)+M-1}$ to $s_{m(M+P)+M+P-1}$ however again fall into a guard interval and accordingly again equal zero. For this reason, for the upper summation limit, M – 1 may always be written.

Insertion of these summation limits into equation (18) yields

$$Y_l = \sum_{k=0}^{P} h_k\, e^{-j\frac{2\pi}{2M}kl} \sum_{n=0}^{M-1} s_{m(M+P)+n}\, e^{-j\frac{2\pi}{2M}nl} \tag{19}$$

$$= \mathrm{FFT}_{2M}\{\mathbf{h}\}(l)\ \mathrm{FFT}_{2M}\{\mathbf{a}_{mM}\}(l)\,, \tag{20}$$

the following being valid: $H_k = 0$ for $k > P$ and $s_{m(M+P)+n} = 0$ for $n \geq M$. **h** is the impulse response of

the channel, $\mathbf{h}^T = [h_0\ h_1 \ldots h_P]$. The vector a_{mM} is the IFFT of the length M of the data block A_{mM} to be transmitted, accordingly

$$Y_l = \mathrm{FFT}_{2M}\{\mathbf{h}\}(l)\ \mathrm{FFT}_{2M}\{\mathrm{IFFT}_M\{A_{mM}\}\}(l)\ . \tag{21}$$

The expression $\mathrm{FFT}_{2M}\{\mathrm{IFFT}_M\{ A_{mM}\}\}(l)$ is examined more closely.

$$\mathrm{FFT}_{2M}\{\mathrm{IFFT}_M\{A_{mM}\}\}(l) = \sum_{k=0}^{M-1}\left(\frac{1}{M}\sum_{n=0}^{M-1} A_{mM+n}\, e^{j\frac{2\pi}{M}nk}\right) e^{-j\frac{2\pi}{2M}kl} \tag{22}$$

$$= \frac{1}{M}\sum_{k=0}^{M-1}\sum_{n=0}^{M-1} A_{mM+n}\, e^{j\frac{2\pi}{2M}k(2n-l)} \tag{23}$$

Interpretation of the above mentioned expression for even-numbered $l = 2r$ yields

$$\mathrm{FFT}_{2M}\{\mathrm{IFFT}_M\{A_{mM}\}\}(2r) = \frac{1}{M}\sum_{k=0}^{M-1}\sum_{n=0}^{M-1} A_{mM+n}\, e^{j\frac{2\pi}{2M}k(2n-2r)} \tag{24}$$

$$= \frac{1}{M}\sum_{k=0}^{M-1}\sum_{n=0}^{M-1} A_{mM+n}\, e^{j\frac{2\pi}{M}k(n-r)} \tag{25}$$

$$= \frac{1}{M}\sum_{n=0}^{M-1} A_{mM+n}\sum_{k=0}^{M-1} e^{j\frac{2\pi}{M}k(n-r)} \tag{26}$$

$$= \frac{1}{M}\sum_{n=0}^{-1} A_{mM+n} M\,\delta_n^r \tag{27}$$

$$= \frac{1}{M} A_{mM+r} M = A_{mM+r}\ . \tag{28}$$

With this result, equation (20) becomes

$$Y_{2r} = \mathrm{FFT}_{2M}\{\mathbf{h}\}(2r)\ A_{mM+r}\ . \tag{29}$$

The 2M FFT of $y_{m(M+P)}$ interpreted at $2r$ accordingly is the r^{th} symbol of the m^{th} block, A_{mM+r}, multiplied by the spectrum of the channel H at the frequency $\frac{2\pi}{2M}2r$. For equalization, the same method may be used as when a cyclical prefix is being used.

Since in equation (29) the even-numbered indices only are of interest, the FFT of the length 2M in equation (14) may easily be brought back to an FFT of the length M. The block on which the FFT of the length 2M is used has a length of $M + P$, it is extended to 2M by means of zeros.

$$\mathrm{FFT}_{2M}\{y_{m(M+P)}\}(2r) = \sum_{n=0}^{2M-1} y_{m(M+P)+n}\, e^{j\frac{2\pi}{M}2nr} \tag{30}$$

$$= \sum_{n=0}^{M-1} y_{m(M+P)+n}\, e^{j\frac{2\pi}{M}nr} + \sum_{n=M}^{2M-1} y_{m(M+P)+n}\, e^{j\frac{2\pi}{M}nr} \tag{31}$$

$$= \sum_{n=0}^{M-1} y_{m(M+P)+n}\, e^{j\frac{2\pi}{M}nr} + \sum_{n=0}^{M-1} y_{m(M+P)+M+n}\, e^{j\frac{2\pi}{M}(M+n)r} \tag{32}$$

$$= \sum_{n=0}^{M-1} \left(y_{m(M+P)+n} + y_{m(M+P)+M+n}\right)\, e^{j\frac{2\pi}{M}nr} \tag{33}$$

$$= \mathrm{FFT}_{M}\{y_{m(M+P)<0^{M-1}>} + y_{m(M+P)<M^{2M-1}>}\}(r) \tag{34}$$

As may be seen from equation (34), the even-numbered indices of a 2M FFT can be calculated by way of an FFT of the length M. The only additional step to be taken is to sum up the two blocks. Considering that the second block only contains *P* of zero different elements, *P* additional additions are necessary.

CLAIMS

1. Method of transmitting data by a multiple carrier method, e.g. DMT (Discrete Multitone) in a transmission channel in which the data are combined in a transmitter into blocks with the same number of information symbols (M), are modulated and transmitted by an Inverse Fast Fourier Transform (IFFT) and are demodulated in a receiver by the Fast Fourier Transform (FFT), wherein, on the transmitter side, one guard interval for equalization on the side of the receiver is inserted each between the transmitter blocks and transmitted together with them, said guard interval having a length (P) that is greater than or equal to the memory length of the transmission channel, **wherein** the guard interval is transmitted free from signals or without prefix and wherein demodulation is carried out in the receiver by means of the Fast Fourier Transform (FFT) with a length (L) that is greater than or equal to the sum of the length (M) of the information block and the length (P) of the guard interval.

2. Method according to claim 1, **wherein** each information block of the length (M+P) to be transformed in the receiver is lengthened by appending zeros to the transformation length (L).

3. Method according to claim 1 or 2, **wherein** the transformation length (L) of the Fast Fourier Transform (FFT) equals the double length 2·M of the information block.

4. Method according to claim 1, 2 or 3, **wherein** the guard interval is transmitted each time before or after an information block.

5. Method according to one of the claims 1 through 4, **wherein** a desired signal, e.g. pilot signals, is transmitted in the guard interval.

ABSTRACT

Method for transmitting data by a multiple carrier method, e.g. DMT (Discrete Multitone), by which the data are combined in a transmitter into blocks having the same number of information symbols (M), are modulated and transmitted by means of an Inverse Fast Fourier Transform (IFFT) and demodulated in a receiver by the Fast Fourier Transform (FFT) wherein, on the transmitter side, one guard interval for equalization on the side of the receiver is inserted each between the blocks and transmitted together with them, said guard interval being greater than or equal to the memory length of the transmission channel, and wherein the guard interval is transmitted free from signal or without prefix respectively, and demodulation is carried out in the receiver by means of the Fast Fourier Transform (FFT) with a length (L) that is greater than or equal to the sum of the information block length (M) and the length (P) of the guard interval.

(Fig. 3)

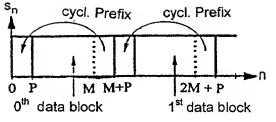

FIG. 1

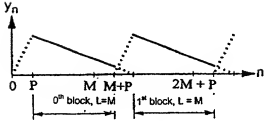

FIG. 2

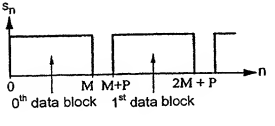

FIG. 3

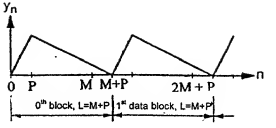
y_n
0
P
M
M+P
2M + P
n
0th block, L=M+P
1st data block, L=M+P

FIG.4

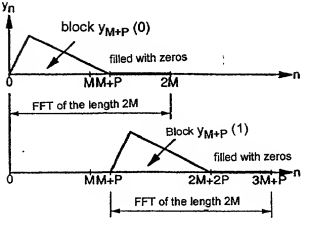
y_n
block y_{M+P} (0)
filled with zeros
0
MM+P
2M
n
FFT of the length 2M
Block y_{M+P} (1)
filled with zeros
0
MM+P
2M+2P
3M+P
n
FFT of the length 2M

FIG.5

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (Includes Reference to Provisional and PCT International Applications)	Attorney's Docket No. 032287-021

As a below named inventor, I hereby declare that:
My residence, post office address and citizenship are as stated below next to my name;
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD FOR TRANSMITTING DATA BLOCKS WITHOUT PREFIX IN THE GUARD INTERVAL, SAID DATA BLOCKS ARE DEMODULATED BY MEANS OF FFT WITH A LENGTH GREATER OR EQUAL THE SYMBOL PERIOD

the specification of which (check only one item below):

☐ is attached hereto.

☐ was filed as United States application
Number _____
on _____
and was amended
on _____ (if applicable).

☒ was filed as PCT international application
Number PCT/AT99/00311
on 21 December 1999
and was amended
on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 (a)-(e) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. §119:

COUNTRY (if PCT, indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. §119
AUSTRIA	2128/98	21 December 1998	X Yes _ No
			_ Yes _ No
			_ Yes _ No
			_ Yes _ No
			_ Yes _ No

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONT'D) (Includes Reference to Provisional and PCT International Applications)	Attorney's Docket No. 032287-021

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

(Application Number) (Filing Date)

(Application Number) (Filing Date)

I hereby claim the benefit under Title 35, United States Code, §120 of any United States applications(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose to the Office all information known to me to be material to the patentability as defined in Title 37, Code of Federal Regulations §1.56, which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. §120:

U.S. APPLICATIONS		STATUS *(check one)*		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.				
PCT APPLICATION NO.	PCT FILING DATE	U.S. APPLICATION NUMBERS ASSIGNED (if any)		

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONT'D) (Includes Reference to Provisional and PCT International Applications)	Attorney's Docket No. 032287-021

I hereby appoint the following attorneys and agent(s) to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and to transact all business in connection with international applications directed to said invention:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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